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Stewart's Educational Series.

'WRINKLES'

IN

ALGEBRA, ARITHMETIC, EUCLID,
MECHANICS, CHEMISTRY, HEAT AND LIGHT,
MAGNETISM AND ELECTRICITY,

BEING

FORMULÆ, DEFINITIONS, LAWS AND PROPOSITIONS

FOR THE USE OF

LONDON MATRICULATION AND OTHER STUDENTS

BY

ARTHUR G. MADGE, B.A.

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PREFACE.

This little book pretends to be nothing more than a summary of Formulæ, &c., for the use of Matriculation students, who, after reading, require to remember accurately and thoroughly the Propositions, Theorems, &c., they have read.

Each section should be revised frequently, and the book being so small, can easily be carried in one's pocket and used whenever, amidst other work, there may be a few minutes' leisure. By using the book daily in this way, the student will soon thoroughly know the skeleton of his work, and then in his later revisions will be able, with his additional information, to clothe it.

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'WRINKLES' IN ALGEBRA, ARITHMETIC, &c.

SECTION I.

ALGEBRA.

1. (α) $(a+b)^2 = a^2 + 2ab + b^2.$

(β) $(a-b) = a^2 - 2ab + b^2.$

(γ) $(a+b)\ (a-b) = a^2 \qquad - b^2.$

2. $(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3.$

$(a-b)^3 = a^3 - 3a^2b + 3ab^2 - b^3.$

3. To square a trinomial such as $(a+b-c)$, treat $(a+b)$ as one term, and then square as in (1) β.

$(a+b-c)^2 = \{(a+b)-c\}^2 = a^2 + 2ab + b^2 - 2ac - 2bc + c^2.$

4. To square a quantity with four terms as $(a+b-c+d)$, bracket so as to reduce it to form of (1) β.

$(a+b-c+d)^2 = \{(a+b)-(c-d)\}^2 =$

$$a^2 + 2ab + b^2 - 2\ (ac + bc - ad - bd) + c^2 - 2cd + d^2.$$

5. Let n be any whole number, then

(α) $a^n + b^n$ is divisible by $a+b$ when n is odd.
$a^n + b^n$ " $a-b$ never.

(β) $a^n - b^n$ is divisible by $a+b$ when n is even.
$a^n - b^n$ " $a-b$ always.

6. When $a^n - b^n$ is divided by $a-b$, all terms of quotient will be + as $\dfrac{a^4 - b^4}{a-b} = a^3 + a^2b + ab^2 + b^3.$

7. When $a^n - b^n$ is divided by $a+b$, then the terms are alternately + and −, as $\dfrac{a^4 - b^4}{a+b} = a^3 - a^2b + ab^2 - b^3.$

8. $a^0 = 1$.

9. Let $x^2 + px + q = o$ be taken as type of quadratic equation, then (*a*) a quadratic equation has two roots and only two.

(*b*) the roots of the equation are :—

i. $$-\frac{p}{2} + \sqrt{\left(\frac{p^2}{4} - q\right)}$$

ii. $$-\frac{p}{2} - \sqrt{\left(\frac{p^2}{4} - q\right)}$$

iii. The sum of the roots = coefficient of second term with sign changed.

iv. The product of the roots = the last term.

10. The equation to $x^2 + px + q = 0$ has its roots.

(*a*) real and different when p^2 is greater than $4q$.

(*b*) real and equal when p^2 is equal to $4q$.

(*c*) impossible and different when p^2 is less than $4q$.

11. Arith. Prog.

s = sum of terms, n = number of terms, a = first term, d = common difference, l = last term.

Then (*a*) $l = a + (n-1)d$

(*β*) $s = \frac{n}{2}(a + l)$

substituting value of l in (*β*) $s = \frac{n}{2}\{2a + (n-1)d\}$

12. Geom. Prog.

s = sum of terms, a = first term, r = constant factor, n = number of terms.

Then i. n^{th} term $= ar^{n-1}$

ii. $$s = \frac{a(r^n - 1)}{r - 1} \text{ or } \frac{a(1 - r^n)}{1 - r}$$

iii. To sum a series of terms to infinity

$$s = \frac{a}{1 - r}$$

13. The Arith. mean between a and b is $\frac{a+b}{2}$

" Geom. " $\sqrt{ab}$

SECTION II.

ARITHMETIC.

1. Abstract numbers are numbers in general, and have no reference to one thing more than another, as 9, 11.

2. Concrete numbers are applied to some particular object, as 9 cows, 11 horses.

3. A prime number is one that can only be divided by itself and unity without a remainder; and numbers are prime to each other when no number but unity will divide them without a remainder.

4. Composite numbers are such as are produced by the multiplication of two or more prime numbers.

5. To multiply by 5, 25, 125, 625,

(*a*)	To multiply	by 5	add 1	cypher	to the number	and	÷ by	2
(*b*)	"	25	"	2 cyphers	"		÷ "	4
(*c*)	"	125	"	3 "	"		÷ "	8
(*d*)	"	625	"	4 "	"		÷ "	16

Similar rules can be found to multiply by 1·25, 62·5, $333\frac{1}{3}$, &c.

6. To divide by 25, 125, &c.

(*a*)	25	Multiply	by 4	and cut off	2	figures	as decimals.
(*b*)	125	"	8	"	3	"	
(*c*)	625	"	16	"	4	"	

7. To multiply by 99, 999, &c.

(*a*) By 99 annex two cyphers to the multiplicand and subtract the original multiplicand from it.

(*b*) By 999 annex three cyphers to the multiplicand and subtract the original multiplicand from it.

8. To square numbers use formula $(a+b)^2 = a^2 + 2ab + b^2$ thus: $(907)^2 = (900+7)^2 = 810000 + 12600 + 49 = 822649$.

9 If two numbers are to be multiplied together which are respectively the sum and difference of two numbers, it is advantageous to use formula $(a+b)\ (a-b)=a^2-b^2$ thus: $287 \times 313 = (300-13)\ (300+13) = 90000 - 169 = 89831$.

10. Any number is divisible by 2 without remainder if its last figure is divisible by 2.

Any number is divisible by 4 without remainder if its last 2 figures are divisible by 4.

Any number is divisible by 8 without remainder if its last 3 figures are divisible by 8.

11. Any number is divisible by 5 without remainder if its last figure is divisible by 5.

Any number is divisible by 25 without remainder if its last 2 figures are divisible by 25.

Any number is divisible by 125 without remainder if its last 3 figures are divisible by 125.

12. Any number is divisible by 9 if the sum of its figures be divisible by 9.

13. The tables of weights and measures should be known thoroughly. The following are often useful:—

	1 lb. Avoirdupois	=	7000 grains Troy.
(*a*)	1 lb. Troy	=	5760 "
(*b*)	6 feet	=	1 fathom.
(*c*)	100 links	=	1 chain.
(*d*)	22 yards	=	1 chain.
(*e*)	4 inches	=	1 hand (used in measuring horses).

14. Rule for greatest common measure:—

(*a*) For two numbers:—Divide the greater by the less, the divisor by the remainder, and so on until nothing remains. The last divisor is the G.C.M.

(*b*) For more than two numbers:—Find the G.C.M. of any two of them; then of this common measure and a third number; then of this last found common measure and a

fourth, &c. The last common measure found will be the G.C.M. of all the numbers.

15. In least common multiple:—It is best in dividing the numbers to begin with 2, and to repeat this as often as possible, and then to divide by the other prime numbers in a similar way.

16. *Decimals.*

(1) To multiply a decimal by 10, 100, 1000, &c., we remove the decimal point 1, 2, 3, places to the right.

(2) To divide a decimal by 10, 100, 1000, we remove the decimal point 1. 2. 3. places to the left.

(3) Rule for division of decimals:—Divide as in integers, annexing as many cyphers to the dividend as may be thought necessary; then point off from the right of the quotient as many decimal places as the dividend has more than the divisor, making up any deficiency by prefixing cyphers.

(4) *Recurring Decimals.*

(*a*) If the denominator of a vulgar fraction in its lowest terms be composed of 2 and 5, or of one of them, or of powers of 2 and 5, or one of them, then it can be brought out to a *finite* or *terminating* decimal. If this be not the case then the division of the numerator by the denominator will never terminate, and a decimal of this kind is called recurring or circulating.

(*b*) To convert a repeating decimal to a vulgar fraction.

Rule.—For the numerator taken the given decimal, minus the non-repeating part, and for the denominator put down as many 9's as there are figures in the repeating part, followed by as many cyphers as there are figures in the non-repeating part.

(*c*) Addition and subtraction of repeating decimals.

Rule.—Arrange as in terminating decimals, carry on the repeating part to two or three more places than the number required, taking care that the last figure retained in the

answer be increased by one if the succeeding figure be five or more.

(*d*) Multiplication and division of repeating decimals.

Rule.—Convert the decimals to vulgar fractions, multiply or divide in the ordinary way, and then, if necessary, reduce the result again to a decimal.

17. The square root of a number is a number which multiplied by itself will give the given number.

18. Rule for Pointing. Point off the number into periods of two figures each, beginning at the right if a whole number, and at the left if a decimal. If one figure remains over at the left in integers it is considered a period, but if one remains over at the right in decimals, a cypher is added to complete the period.

19. It is of advantage to recognise the squares of the following numbers at sight:—

$13^2 = 169.$	$18^2 = 324.$	$23^2 = 529.$
$14^2 = 196.$	$19^2 = 361.$	$24^2 = 576.$
$15^2 = 225.$	$20^2 = 400.$	$25^2 = 625.$
$16^2 = 256.$	$21^2 = 441.$	$26^2 = 676.$
$17^2 = 289.$	$22^2 = 484.$	$27^2 = 729.$
		$28^2 = 784.$
		$29^2 = 841.$

SECTION III.

EUCLID.

A. General Explanations:—

1. A Proposition in Euclid is something required to be done or to be proved.
2. A Problem proposes something to be done.

3. A Theorem makes a statement, the truth of which it is proposed to demonstrate.
4. A Postulate is a problem so simple that the possibility of doing it is self-evident and requires no proof.
5. An Axiom is a theorem, the truth of which is admitted without proof.
6. A Corollary is an inference which rises immediately from the discussion of the proposition to which it is affixed.

Book I.

Prop. 1. Problem.—To describe an equilateral triangle upon a given finite straight line. (Refs.: Def. 15; ax. 1; posts. 1, 3.)

Prop. 2. Problem.—From a given point to draw a straight line equal to a given straight line. (Refs.: Prop. 1; posts. 1, 2, 3; ax. 1, 3; def. 15.)

Prop. 3. Problem.—From the greater of two given straight lines to cut off a part equal to the less. (Refs.: Prop. 2; post. 3; ax. 1; def. 15.)

Prop. 4. Theorem.—If two triangles have two sides of the one equal to two sides of the other, each to each, and have likewise the angles contained by those sides equal to one another, they shall have their bases or third sides equal, the two triangles shall be equal, and their other angles shall be equal, each to each, viz., those to which the equal sides are opposite. (Refs.: Axs. 8, 10.)

Prop. 5. Theorem.—The angles at the base of an isosceles triangle are equal to one another; and if the equal sides be produced, the angles upon the other side of the base shall also be equal. (Refs.: Props. 3, 4; ax. 3.)

Corollary.—Hence every equilateral triangle is also equiangular.

Prop. 6. Theorem.—If two angles of a triangle be equa to one another, the sides also which subtend, or are opposite to the equal angles, shall be equal to one another. (Refs.: Props. 3, 4.)

Corollary.—Hence every equiangular triangle is also equilateral.

Prop. 7. Theorem.—Upon the same base and upon the same side of it there cannot be two triangles which have their sides, which are terminated in one extremity of the base, equal to one another, and likewise those which are terminated in the other extremity. (Refs.: Prop. 5; ax. 9.)

Prop. 8. Theorem.—If two triangles have two sides of the one equal to two sides of the other, each to each, and have likewise their bases equal, the angle which is contained by the two sides of the one shall be equal to the angle contained by the two sides equal to them of the other. (Refs.: Prop. 7; ax. 8.)

Prop. 9. Problem.—To bisect a given rectilineal angle, that is, to divide it into two equal parts. (Refs.: Props. 1, 3, 8.)

Prop. 10. Problem.—To bisect a given finite straight line, that is, to divide it into two equal parts. (Refs.: Props. 1, 4, 9.)

Prop. 11. Problem.—To draw a straight line at right angles to a given straight line from a given point in the same. (Refs.: Props. 1, 3, 8; ax. 1; def. 10.)

Corollary.—Two straight lines cannot have a common segment.

Prop. 12. Problem.—To draw a straight line perpendicular to a given straight line of unlimited length from a given point without it. (Refs.: Props. 8, 10; post. 3; defs. 10, 15.)

Prop. 13. Theorem.—The angles which one straight line makes with another upon one side of it are either two right

angles, or are together equal to two right angles. (Refs.: Prop. 11; axs. 1, 2; def. 10.)

Prop. 14. Theorem.—If, at a point in a straight line, two other straight lines upon the opposite sides of it make the adjacent angles equal together to two right angles, these two straight lines shall be in one and the same straight line. (Refs.: Prop. 13; axs. 1, 3.)

Prop. 15. Theorem.—If two straight lines cut one another, the vertical or opposite angles shall be equal. (Refs.: Prop. 13; axs. 1, 3.)

Corollary I.—If two straight lines cut one another, the angles which they make at the point where they cut are together equal to four right angles.

Corollary II.—And, consequently, that all the angles made by any number of lines meeting in one point are together equal to four right angles.

Prop. 16. Theorem.—If one side of a triangle be produced, the exterior angle shall be greater than either of the interior opposite angles. (Refs.: Props. 3, 4, 10, 15; ax. 9.)

Prop. 17. Theorem.—Any two angles of a triangle are together less than two right angles. (Refs.: Props. 13, 16; ax. 4.)

Prop. 18. Theorem.—The greater side of every triangle is opposite the greater angle. (Refs.: Props. 3, 5, 16.)

Prop. 19. Theorem.—The greater angle of every triangle is subtended by the greater side, or has the greater side opposite to it. (Refs.: Props. 5, 18.)

Prop. 20. Theorem.—Any two sides of a triangle are together greater than the third side. (Refs.: Props. 3, 5, 19; ax. 9.)

Prop. 21. Theorem.—If from the ends of the side of a triangle there be drawn two straight lines to a point within the triangle, these shall be less than the other

two sides of the triangle, but shall contain a greater angle. (Refs.: Props. 16, 20; ax. 4.)

Prop. 22. Problem.—To make a triangle of which the sides shall be equal to three given straight lines, but any two whatever of these lines must be greater than the third. (Refs.: Prop. 3; post. 3; ax. 1; def. 15.)

Prop. 23. Problem. — At a given point in a given straight line, to make a rectilineal angle equal to a given rectilineal angle. (Refs.: Props. 8, 22.)

Prop. 24. Theorem.—If two triangles have two sides of the one equal to two sides of the other, each to each, but the angle contained by the two sides of one of them greater than the angle contained by the two sides equal to them of the other, the base of that which has the greater angle shall be greater than the base of the other. (Refs.: Props. 3, 4, 5, 19, 23; ax. 9.)

Prop. 25. Theorem.—If two triangles have two sides of the one equal to two sides of the other, each to each, but the base of the one greater than the base of the other, the angle contained by the sides of that which has the greater base shall be greater than the angle contained by the sides equal to them of the other. (Refs.: Props. 4, 24.)

Prop. 26. Theorem.—If two triangles have two angles of the one equal to two angles of the other, each to each, and one side equal to one side, viz., either the side adjacent to the equal angles in each, or the side opposite to them; then shall the other sides be equal, each to each, and also the third angle of the one equal to the third angle of the other. (Refs.: Props. 3, 4, 16; ax. 1.)

Prop. 27. Theorem.—If a straight line falling upon two other straight lines makes the alternate angles equal to one another, these two straight lines shall be parallel. (Refs.: Prop. 16; def. 34.)

Prop. 28. Theorem.—If a straight line falling upon two other straight lines make the exterior angle equal to the interior and opposite, upon the same side of the line, or make the interior angles upon the same side together equal to two right angles, the two straight lines shall be parallel to one another. (Refs.: Props. 13, 15, 27; axs. 1, 3.)

Prop. 29. Theorem.—If a straight line fall upon two parallel straight lines, it makes the alternate angles equal to one another, the exterior angle equal to the interior and opposite upon the same side; and also the two interior angles upon the same side equal to two right angles. (Refs.: Props. 13, 15; axs. 1, 2, 4, 12.)

Prop. 30. Theorem.—Straight lines which are parallel to the same straight line are parallel to one another. (Refs.: Props. 27, 29; ax. 1.)

Prop. 31. Problem.—To draw a straight line through a given point, parallel to a given straight line. (Refs.: Props. 23, 27.)

Prop. 32. Theorem.—If a side of any triangle be produced, the exterior angle is equal to the two interior and opposite angles; and the three interior angles of every triangle are equal to two right angles. (Refs.: Props. 13, 29, 31; axs. 1, 2.)

Corollary I.—All the interior angles of any rectilineal figure, together with four right angles, are equal to twice as many right angles as the figure has sides. (Refs.: Prop. 15; cor. II.)

Corollary II.—All the exterior angles of any rectilineal figure are together equal to four right angles. (Refs.: Props. 13, 32; cor. I.; axs. 1, 3.)

Prop. 33. Theorem.—The straight lines which join the extremities of two equal and parallel straight lines towards the same parts, are also themselves equal and parallel. (Refs.: Props. 4, 27, 29.)

Prop. 34. Theorem.—The opposite sides and angles of a parallelogram are equal to one another, and the diagonal bisects it, that is, divides it into two equal parts. (Refs.: Props. 26, 29; ax. 2.)

Prop. 35. Theorem. — Parallelograms upon the same base and between the same parallels are equal to one another. (Refs.: Props. 4, 29, 34; axs. 1, 2, 3, 6.)

Prop. 36. Theorem. — Parallelograms upon equal bases and between the same parallels are equal to one another. (Refs.: Props. 33, 34, 35; ax. 1.)

Prop. 37. Theorem.—Triangles upon the same base and between the same parallels are equal to one another. (Refs.: Props. 31, 34, 35; ax. 7.)

Prop. 38. Theorem.—Triangles upon equal bases and between the same parallels are equal to one another. (Refs.: Props. 31, 34, 36; ax. 7.)

Prop. 39. Theorem.—Equal triangles upon the same base and on the same side of it are between the same parallels. (Refs.: Props. 31, 37; ax. 1.)

Prop. 40. Theorem.—Equal triangles upon the same side of equal bases that are in the same straight line are between the same parallels. (Refs.: Props. 31, 38; ax. 1.)

Prop. 41. Theorem.—If a parallelogram and a triangle be upon the same base and between the same parallels, the parallelogram shall be double of the triangle. (Refs.: Props. 34, 37; ax. 1.)

Prop. 42. Problem.—To describe a parallelogram that shall be equal to a given triangle, and have one of its angles equal to a given rectilineal angle. (Refs.: Props. 10, 23, 31, 38, 41; ax. 6; def. 35.)

Prop. 43. Theorem.—The complements of the parallelograms which are about the diagonal of any parallelogram are equal to one another. (Refs.: Prop. 34; axs. 2, 3.)

Prop. 44. Problem.—To a given straight line, to apply

a parallelogram which shall be equal to a given triangle, and have one of its angles equal to a given rectilineal angle. (Refs.: Props. 15, 29, 31, 42, 43; axs. 1, 9, 12.)

Prop. 45. Problem.—To describe a parallelogram equal to a given rectilineal figure, and having an angle equal to a given rectilineal angle. (Refs.: Props. 14, 29, 30, 42, 44; axs. 1, 2; def. 35.)

Prop. 46. Problem.—To describe a square upon a given straight line. (Refs.: Props. 3, 11, 29, 31, 34; axs. 1, 3; def. 30.)

Prop. 47. Theorem.—In any right-angled triangle, the square which is described upon the side opposite the right angle, is equal to squares described upon the sides which contain the right angle. (Refs.: Props. 4, 14, 31, 41, 46; axs. 2, 6, 11; def. 30.)

Prop. 48. Theorem.—If the square described upon one of the sides of a triangle be equal to the squares described upon the other two sides of it, the angle contained by these two sides is a right angle. (Refs.: Props. 3, 8, 11, 47; axs. 1, 2.)

Book II.

Prop. 1. Theorem.—If there be two straight lines, one of which is divided into any number of parts, the rectangle contained by the two straight lines is equal to rectangles contained by the undivided line and the several parts of the divided line. (Refs.: Props. I., 3, 11, 31, 34.)

Prop. 2. Theorem.—If a straight line be divided into any two parts, the rectangles contained by the whole and each of the parts are together equal to the square on the whole line. (Refs.: I., 46, 31.)

Prop. 3. Theorem.—If a straight line be divided into any two parts, the rectangle contained by the whole and one of the parts is equal to the rectangle contained by the two

parts, together with the square on the aforesaid part. (Refs.: I., 46, 31.)

Prop. 4. Theorem.—If a straight line be divided into any two parts, the square on the whole line is equal to the squares on the two parts, together with twice the rectangle contained by the two parts. (Refs.: I., 46, 31, 29, 5, 6, 34, 43; axs. 1, 3; def. 30.)

Prop. 5. Theorem.—If a straight line be divided into two equal parts and also into two unequal parts, the rectangle contained by the unequal parts, together with the square on the line between the points of section, is equal to the square on half the line. (Refs.: I., 46, 31, 43, 36, 34; axs. 1, 2; II., 4, cor.)

Prop. 6. Theorem.—If a straight line be bisected and produced to any point, the rectangle contained by the whole line thus produced and the part of it produced, together with the square on half the line bisected, is equal to the square on the straight line which is made up of the half and the part produced. (Refs.: I., 46, 31, 36, 43, 34; axs. 1, 2; II., 4, cor.)

Prop. 7. Theorem.—If a straight line be divided into any two parts, the squares on the whole line and on one of the parts are equal to twice the rectangle contained by the whole and that part, together with the square on the other part. (Refs.: I., 43, 34; II., 4, cor.)

Prop. 8. Theorem.—If a straight line be divided into any two parts, four times the rectangle contained by the whole line and one of the parts, together with the square on the other part, is equal to the square on the straight line which is made up of the whole and that part. (Refs.: I., 3, 34, 36, 43; ax. 1; post. 2; II., 4, cor.)

Prop. 9. Theorem.—If a straight line be divided into two equal and also into two unequal parts, the squares on the two unequal parts are together double of the square on half

the line and of the square between the points of section. (Refs.: I., 11, 3, 31, 5, 32, 29, 6, 34, 47.)

Prop. 10. Theorem.—If a straight line be bisected and produced to any point, the square on the whole line thus produced and the square on the part of it produced are together double of the square on half the line bisected and of the square on the line made up of the half and the part produced. (Refs.: I., 11, 3, 31, 29, 12, 5, 15, 32, 6, 34, 47; ax. 12.)

Prop. 11. Problem.—To divide a given straight line into two parts, so that the rectangle contained by the whole and one of the parts may be equal to the square on the other part. (Refs.: I., 46, 10, 3, 47; ax. 3; II., 6.)

Prop. 12. Theorem.—In obtuse angle triangles, if a perpendicular be drawn from either of the acute angles to the opposite side produced, the square on the side subtending the obtuse angle is greater than the squares on the sides containing the obtuse angle by twice the rectangle contained by the side on which, when produced, the perpendicular falls, and the straight line intercepted without the triangle, between the perpendicular and the obtuse angle. (Refs.: I., 47; ax. 2; II., 4.)

Prop. 13. Theorem.—In every triangle, the square on the side subtending an acute angle is less than the squares on the sides containing that angle by twice the rectangle contained by either of these sides, and the straight line intercepted between the perpendicular let fall on it from the opposite angle and the acute angle. (Refs.: I., 47, 16; ax. 2; II., 7, 12, 3.)

Prop. 14. Problem.—To describe a square that shall be equal to a given rectilineal figure. (Refs.: I., 45, 3, 47, 10; ax. 3; II., 5).

Book III.

Prop. 1. Problem.—To find the centre of a given circle (Refs.: I., 10, 11, 8; ax. 11; defs. 10, 15.)

Corollary.—From this it is manifest, that if in a circle a straight line bisect another at right angles, the centre of the circle is in the straight line which bisects the other.

Prop. 2. Theorem.—If any two points be taken in the circumference of a circle, the straight line which joins them shall fall within the circle. (Refs.: I., 5, 16, 19; def. 15; III., 1.)

Prop. 3. Theorem.—If a straight line drawn through the centre of a circle bisect a straight line in it which does not pass through the centre, it shall cut it at right angles; and if it cut it at right angles, it shall bisect it. (Refs.: I., 5, 8, 26; defs. 10, 15; III., 1.)

Prop. 4. Theorem.—If in a circle two straight lines cut one another, which do not both pass through the centre, they do not bisect one another. (Refs.: Ax. 11; III., 1, 3.)

Prop. 5. Theorem.—If two circles cut one another, they shall not have the same centre. (Refs.: Ax. 1; def. 15.)

Prop. 6. Theorem.—If two circles touch one another internally, they shall not have the same centre. (Refs.: Ax. 1; def. 15.)

Prop. 7. Theorem.—If any point be taken in the diameter of a circle which is not the centre of all the straight lines which can be drawn from this point to the circumference, the greatest is that in which the centre is, and the other part of the diameter is the least; and, of any others, that which is nearer to the straight line which passes through the centre is always greater than one more remote; and from the same point there can be drawn to the circumference two straight lines, and only two, which are equal to one another, one on each side of the shortest line. (Refs.: I., 20, 24, 23, 4; ax. 1; def. 15.)

Prop. 8. Theorem.—If any point be taken without a circle, and straight lines be drawn from it to the circumference, one of which passes through the centre; of those which fall on the concave circumference, the greatest is that which passes through the centre; and of the rest, that which is nearer to the one passing through the centre is always greater than one more remote; but of those which fall on the convex circumference, the least is that between the point without the circle and the diameter; and of the rest, that which is nearer to the least is always less than one more remote; and from the same point there can be drawn to the circumference two straight lines, and only two, which are equal to one another, one on each side of the shortest line. (Refs.: I., 20, 24, 23, 4, 21; ax. 1; def. 15; III., 1.)

Prop. 9. Theorem.—If a point be taken within a circle, from which there fall more than two equal straight lines to the circumference, that point is the centre of the circle. (Refs.: III., 7.)

Prop. 10. Theorem.—One circumference of a circle cannot cut another at more than two points. (Refs.: I., def. 15; III., 1, 9, 5.)

Prop. 11. Theorem.—If two circles touch one another internally, the straight line which joins their centres, being produced, shall pass through the point of contact. (Refs.: I., 20; def. 15.)

Prop. 12. Theorem.—If two circles touch one another externally, the straight line which joins their centres shall pass through the point of contact. (Refs.: I., 20; ax. 2; def. 15.)

Prop. 13. Theorem.—One circle cannot touch another at more points than one, whether it touches it on the inside or outside. (Refs.: I., 10, 11; III., 2, 1, 11.)

Prop. 14. Theorem.—Equal straight lines in a circle are equally distant from the centre, and those which are

equally distant from the centre are equal to one another. (Refs.: I., 12, 47; axs. 1, 3, 6, 7; def. 15; III., 1, 3; def. 4.)

Prop. 15. Theorem.—The diameter is the greatest straight line in a circle; and, of all others, that which is nearer to the centre is always greater than one more remote; and the greater is nearer to the centre than the less. (Refs.: I., 12, 20; ax. 2; def. 15; III., def. 5.)

Prop. 16. Theorem.—The straight line drawn at right angles to the diameter of a circle from the extremity of it, falls without the circle; and no straight line can be drawn from the extremity, between that straight line and the circumference, so as not to cut the circle. (Refs.: I., 5, 17, 12, 19; def. 15.)

Corollary.—The straight line drawn at right angles to the diameter of a circle from the extremity of it touches the circle. (Refs.: III., def. 2; III., 2.)

Prop. 17. Problem.—To draw a straight line from a given point, either without or in the circumference, which shall touch a given circle. (Refs.: I., 11, 4; ax. 1; def. 15; III., 1 and 16 cor.)

Prop. 18. Theorem.—If a straight line touch a circle, the straight line drawn from the centre to the point of contact shall be perpendicular to the line touching the circle. (Refs.: I., 17, 19; def. 15.)

Prop. 19. Theorem.—If a straight line touch a circle, and from the point of contact a straight line be drawn at right angles to the touching line, the centre of the circle shall be in that line. (Refs.: Ax. 11; III., 18.)

Prop. 20. Theorem.—The angle at the centre of a circle is double of the angle at the circumference on the same base, that is on the same arc. (Refs.: I., 5, 32.)

Prop. 21. Theorem.—The angles in the same segment of a circle are equal to one another. (Refs.: Axs. 2, 7; III., 1, 20.)

Prop. 22. Theorem.—The opposite angles of any quadri-

lateral figure inscribed in a circle are together equal to two right angles. (Refs.: I., 32; ax. 2; III., 21.)

Prop. 23. Theorem.—On the same straight line and on the same side of it there cannot be two similar segments of circles not coinciding with one another. (Refs.: I., 16, III., 10; def. 11.

Prop. 24. Theorem.—Similar segments of circles on equal straight lines are equal to one another. (Refs.: III., 23.)

Prop. 25. Problem.—A segment of a circle being given, to describe the circle of which it is a segment. (Refs.: I., 10, 11, 6, 23, 4; ax. 1; III., 9.)

Prop. 26. Theorem.—In equal circles, equal angles stand on equal arcs, whether they be at the centres or circumferences. (Refs.: I., 4; ax. 3; III., 24; defs. 1 and 11.)

Prop. 27. Theorem.—In equal circles, the angles which stand on equal arcs are equal to one another, whether they be at the centres or circumferences. (Refs.: I., 23; axs. 7, 1; III., 20, 26.)

Prop. 28. Theorem.—In equal circles equal straight lines cut off equal arcs, the greater equal to the greater, and the less equal to the less. (Refs.: I., 8; ax. 3; III., 1, 26; def. 1.)

Prop. 29. Theorem.—In equal circles, equal arcs are subtended by equal straight lines. (Refs.: I., 4; III., 1, 27; def. 1.)

Prop. 30. Prob.—To bisect a given arc, that is to divide it into two equal parts. (Refs.: I., 10, 11, 4; III., 1, cor. and 28.)

Prop. 31. Theorem.—In a circle the angle in a semicircle is a right angle; but the angle in a segment greater than a semicircle is less than a right angle; and the angle in a segment less than a semicircle is greater than a right angle. (Refs.: I., 5, 32, 17; ax. 2; defs. 15, 10; III., 22.)

Corollary.—If one angle of a triangle equal the other two, it is a right angle. (Refs.: I., 32, and def. 10.)

Prop. 32. Theorem.—If a straight line touch a circle and from the point of contact a straight line be drawn, cutting

the circle, the angles which this line makes with the line touching the circle shall be equal to the angles in the alternate segments of the circle. (Refs.: I., 11, 32, 13; ax. 3; III., 19, 31, 22.)

Prop. 33. Problem.—On a given straight line to describe a segment of a circle containing an angle equal to a given rectilineal angle. (Refs.: I., 10, 11, 4, 23; ax. 1; def. 10; III., 31, 16 cor. and 32.)

Prop. 34. Problem.—From a given circle to cut off a segment containing an angle equal to a given rectilineal angle. (Refs.: I., 23; ax. 1; III., 17. 32.)

Prop. 35. Theorem.—If two straight lines cut one another within a circle, the rectangle contained by the segments of one of them shall be equal to the rectangle contained by the segments of the other. (Refs.: I., 12, 47; axs. 1, 2, 3; II., 5; III., 1, 3.)

Prop. 36. Theorem.—If from any point without a circle two straight lines be drawn, one of which cuts the circle and the other touches it, the rectangle contained by the whole line which cuts the circle and the part of it without the circle shall be equal to the square on the line which touches it. (Refs.; I., 12, 47; axs. 2, 3; II., 6; III., 18, 1, 3.)

Prop. 37. Theorem.—If from any point without a circle there be drawn two straight lines, one of which cuts the circle and the other meets it, and if the rectangle contained by the whole line which cuts the circle, and the part of it without the circle be equal to the square on the line which meets the circle, the line which meets the circle shall touch it. (Refs.: I., 8; ax. 1; def. 15; III., 17, 1, 18, 36, and 16 cor.)

Book IV.

Prop. 1. Problem.—In a given circle, to place a straight line equal to a given straight line, which is not greater than the diameter of the circle. (Refs.: I., 3; ax. 1; def. 15)

Prop. 2. Problem.—In a given circle, to inscribe a triangle equiangular to a given triangle. (Refs.: I., 23, 32; ax. 11, 3, 1; III., 7, 32.)

Prop. 3. Problem.—About a given circle, to describe a triangle equiangular to a given triangle. (Refs.: I., 23, 13, 32; ax. 3, 11; III., 1, 17, 18.)

Prop. 4. Problem.—To inscribe a circle in a given triangle. (Refs.: I., 9, 12, 26; axs. 11, 1; III., 16 cor.)

Prop. 5. Problem.—To describe a circle about a given triangle. (Refs.: I., 10, 11, 4; ax. 1; III., 31 cor.)

Prop. 6. Problem.—To inscribe a square in a given circle. (Refs.: I., 11, 4; III., 1, 31.)

Prop. 7. Problem.—To describe a square about a given circle. (Refs.: I., 11, 28, 34; III., 1, 17, 18.)

Prop. 8. Problem.—To inscribe a circle in a given square. (Refs.: I., 10, 31, 34; ax. 7; def. 30; III., 16 cor.)

Prop. 9. Problem.—To describe a circle about a given square. (Refs.: I., 8, 6; ax. 7.)

Prop. 10. Problem.—To describe an isosceles triangle, having each of the angles at the base double of the third angle. (Refs.: I., 32, 5, 6; ax. 1, 2, 6; II., 11; III., 32, 37; IV., 1, 5.)

Prop. 11. Problem.—To inscribe an equilateral and equiangular pentagon in a given circle. (Refs.: I., 9; ax. 2; III., 26, 27, 29; IV., 2, 10.)

Prop. 12. Problem.—To describe an equilateral and equiangular pentagon about a given circle. (Refs.: I., 47, 8, 4, 26; axs. 1, 7, 36; III., 17, 18, 27.)

Prop. 13. Problem.—To inscribe a circle in a given equilateral and equiangular pentagon. (Refs. I., 9, 4, 12, 26; III., 16.)

Prop. 14. Problem.—To describe a circle about a given equilateral and equiangular pentagon. (Refs.: I., 9, 6; ax. 7.)

PROP. 15. Problem.—To inscribe an equilateral and equiangular hexagon in a given circle. (Refs.: I., 5, cor. 32, 13, 15; ax. 1; III., 1, 26, 29, 27.)

PROP. 16. Problem.—To inscribe an equilateral and equiangular quindecagon in a given circle. (Refs.: III., 30; IV., 2, 11, 1.)

SECTION IV.

MECHANICS.

A. Dynamics—

Def. of Velocity.—The velocity of a point in motion at any moment is the degree of quickness of the motion of the point at that moment.

Laws of Motion—

i. Every body continues in a state of rest or of uniform motion in a straight line, except in so far as it may be compelled to change that state by force acting upon it.

ii. Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.

iii. Action and re-action are equal and opposite; that is, to every action there is a corresponding re-action equal in magnitude but opposite in direction.

Acceleration.—Acceleration is used as an abbreviation for 'velocity added in a moment of time.'

Formulae.—s = space; v = velocity; t = time in seconds.

Then (*a*) $s = vt$.

(*b*) Space described in the nth second under acceleration 'f.'

$s = \frac{1}{2}f(2n - 1)$.

(*c*) Space described in n seconds under acceleration 'f.'

$s = \frac{1}{2}ft^2$.

(*d*) $v^2 = 2fs$.

If 'g' (32 feet) be substituted for 'f' in the formulae above, they will then answer for bodies moving under the action of gravity.

$$(a')\ s = \tfrac{1}{2}g(2n-1)\,;\ (b')\ s = \tfrac{1}{2}gt^2\,;\ (c')\ v^2 = 2gs.$$

Formulae for motion of bodies in a straight line under the influence of a uniform force, with a given initial velocity.

The formulae will correspond to those given above *a*, *b*, *c*, *d*.

u = the given initial velocity.

(*a*) $v = u \pm ft$.

(*b*) $s = u \pm \frac{1}{2}f(2n-1)$.

(*c*) $s = ut \pm \frac{1}{2}ft^2$.

(*d*) $v^2 = u^2 \pm 2fs$.

N.B.—(*a*) The original velocity u is destroyed in time $\frac{u}{f}$

(*b*) and the space described in that time is $\frac{u^2}{2f}$

Most important use of this note is in problems respecting gravity.

Force.—Force is that which produces acceleration in mass.

Force = mf (m = mass, and f = acceleration).

Mass.—The mass of a body or particle is the quantity of matter which it contains.

Momentum.—Momentum is the product of mass moved × by velocity.

Work.—Work is the production of motion against resistance.

Energy.—Energy is the capacity for doing work. Energy may be Potential or Kinetic.

(*a*) Potential Energy is the capacity for doing work possessed by mass in virtue of its *position.*

(*b*) Kinetic Energy is the capacity for doing work possessed by mass in virtue of its *mass velocity.*

Conservation of Energy.—Energy is indestructible ; it can change its form, but its quantity remains unchanged.

Parallelogram of Velocities.—If a body have communicated to it simultaneously two velocities which are represented in magnitude and direction by two straight lines drawn from a point, then the resultant velocity will be represented in magnitude and direction by the diagonal drawn from that point of which the two straight lines are adjacent sides of the parallelogram.

Parallelogram of Accelerations.—This may be deduced from the Parallelogram of Velocities by reading 'acceleration' for 'velocity.'

Parallelogram of Forces.—If two forces acting on a particle be represented in magnitude and direction by two straight lines drawn from a point, and a parallelogram be constructed having these straight lines as adjacent sides, then the resultant of the two forces is represented in magnitude and direction by that diagonal of the parallelogram which passes through the point.

Triangle of Forces.—If three forces acting on a particle be represented in magnitude and direction by the sides of a triangle taken in order, they will keep the particle in equilibrium.

Moments.—The moment of a force about a point is the name given to power which that force has to turn any body round that point.

In estimating the power of force to turn a body round a fixed point we must consider—

1. The magnitude of the force.
2. The perpendicular distance of line of action of the force from the fixed point.

Propositions on Moments.—

I. The moment of a force about a point in its own line of action is zero.

II. The algebraic sum of the moments of two parallel forces about any point in their plane equals the moment of their resultant about that point.

III. The algebraic sum of the moments of two forces meeting in a point and acting in one plane about any point in the plane, equals the moment of their resultant about that point.

IV. The algebraic sum of the moments of two forces acting in one plane and meeting in a point about any point in the line of action of the resultant is zero.

B. Statics.—

Centre of Gravity.—The point at which the weight of a body or system of bodies may always be supposed to act is called its 'mass-centre' or 'centre of gravity.'

Centre of Gravity of Parallelogram.—1. The centre of gravity of a ▭ is the intersection of the straight lines which join the middle points of opposite sides.

Centre of Gravity of Triangle.—2. The centre of gravity of a triangle is in the line joining middle point of base to opposite angle, and $\frac{1}{3}$ of its length from base.

The centre of gravity of a triangle coincides with centre of gravity of 3 equal heavy particles placed at angular points of the triangle.

Centre of Gravity of Cone.—3. The centre of gravity of cone is in the line joining centre of gravity of base with the vertex, and $\frac{1}{4}$ of its length up.

Centre of Gravity of Sphere.—4. The centre of gravity of a sphere is the same as its geometrical centre.

Equilibrium.—

(*a*) A body is said to be in *unstable equilibrium* when, on the slightest disturbance, it moves away from its former position.

(*b*) A body is said to be in *stable equilibrium* if it returns to its former position.

(*c*) If a body remains in the new position which the displacement has given it, the position is said to be *neutral*.

A body placed with its base upon a plane surface will stand or fall according as the vertical line through its centre of gravity falls within or without the base.

C. Hydrostatics.—

1. *Pascal's Law*—

Pressure exerted upon a mass of liquid is—

(*a*) Transmitted undiminished in all directions.

(*b*) Acts with the same force on all equal surfaces.

(*c*) And in a direction at right angles to those surfaces.

2. *Pressure in liquids under gravity*—

(*a*) The pressure in each layer is proportional to depth.

(*b*) With different liquids and same depth, pressure is proportional to density of liquid.

(*c*) Pressure is the same at all points of the same horizontal layer.

The upward pressure of liquids is governed by the same laws as the downward pressure.

Equilibrium of a Liquid.—In order that a liquid may remain at rest

(*a*) Its surface must be everywhere perpendicular to the resultant of the forces which act on the molecules of the liquid.

(*b*) Every molecule of the mass of the liquid must be subject in every direction to equal and contrary pressures.

Archimedes' Principle.—A body immersed in a liquid loses a part of its weight equal to the weight of displaced liquid.

Conditions of Equilibrium in Floating Bodies.—

I. The floating body must displace a volume of liquid whose weight equals that of the body.

II. The centre of gravity of the floating body must be in the same vertical line as that of the fluid displaced.

III. The equilibrium of a floating body is stable or unstable as the metacentre is above or below the centre of gravity.

Specific Gravity.—The Specific Gravity of a body is the number which expresses the relation of the weight of a given volume of this body to the weight of the same volume of distilled water at 4° C.

There are three methods of determining the specific gravity of solids and liquids.

(*a*) Method of Hydrostatic Balance.
(*b*) " Hydrometer.
(*c*) " Specific Gravity Bottle.

Formulae.—(*a*) To compare the Specific Gravities of a solid and a fluid by means of Hydrostatic Balance.

Case I. When the solid is of greater Specific Gravity than the fluid—

$$\left.\begin{array}{ll} \text{Let } v & = \text{Vol. of solid.} \\ \text{" } s & = \text{Specific Gravity of solid} \\ \text{" } s' & = \text{" fluid} \\ \text{" } w & = \text{weight of solid in air} \\ \text{" } w' & = \text{" fluid} \end{array}\right\} \text{then } \frac{s}{s'} = \frac{w}{w - w'}$$

Case II. When the solid is of less Specific Gravity than the fluid—

Attach a 'sinker' to the solid, which will make the solid sink with it in the fluid—

Let w = weight of the two bodies in air.
" w'' = " solid in air.
" x = " two bodies in fluid.
" y = " sinker in air.
" z = " " fluid.

$$\text{then } \frac{s}{s'} = \frac{w''}{w - x - y + z}$$

Nicholson's Hydrometer.—(*b*) I. To compare Specific Gravities of a solid and a fluid.

Let w = weight of substance which causes the hydrometer to sink in fluid to the mark on the steel wire when placed in upper dish.

Let x = weight which must be added to the solid whose Specific Gravity is to be found to make the hydrometer sink in fluid to the mark on the steel wire.

Let y = weight of substance which must be put in upper dish to make the hydrometer sink in fluid to mark on the steel wire when the solid is placed in the lower dish,

$$\text{then } \frac{\text{Specific Gravity of solid}}{\text{Specific Gravity of fluid}} = \frac{w - x}{y - x}$$

II. To compare the Specific Gravities of two fluids by weighing the same solid in each.

Let s and s' = Specific Gravities of the fluids.

" w and w' = weights of the solid when immersed in respective fluids.

" W = weight of solid in air—

$$\text{then } \frac{s}{s'} = \frac{W - w}{W - w'}$$

D. Gases. Boyle and Mariotte's Law—

The temperature remaining the same, the volume of a given quantity of gas is inversely as the pressure which it supports.

But this law has now been proved to be only approximately true.

Charles' Law.—All gases expand $\frac{1}{273}$ of their volume at 0° C for every increase in temperature of 1° C.

This fraction is called the 'coefficient of expansion of gases.'

Graham's Law.—The rates of the diffusion of gases are inversely proportional to their densities.

Atmospheric Pressure.—The pressure of the atmosphere = 14·7 lbs. on a square inch—roughly speaking 15 lbs.

Suction Pump.—When water fills the pipe and barrel as far as the spout, the effort necessary to raise piston = the weight of a column of water, the base of which is the piston and the height the vertical distance of the spout from the level of water in reservoir, that is, the height to which the water is raised.

SECTION V.

CHEMISTRY.

Chemical Combination—

1. Chemical Combination consists in the union of the small indivisible particles of matter called 'atoms.' These atoms are all supposed to be of the same size with the exceptions—

Phosphorus and Arsenic, which are half the usual size; Zinc, Cadmium, and Mercury, which are double the usual size.

2. Avogadro's Law—

The densities of all the elements known in a gaseous state are identical with their atomic weights.

The vapour densities of compound substances are nearly always half their molecular weight.

3. Laws of Chemical Combination—

A. *Law of Constant Proportion.*

The same body is invariably composed of the same elements united in the same proportions.

B. *Law of Multiple Proportion.*

When an element unites with another in different proportions, the higher proportions are invariably multiples of the lowest.

C. *Law of Reciprocal Proportion.*

If two bodies, A and B, separately combine with a third body C, the proportions of A and B which unite with C are measures or multiples of the proportions in which A and B combine together.

Def. of Acid.—An acid is a body containing Hydrogen, which may be replaced by a metal (or group of elements) when presented to it in the form of an oxide or hydrate.

Acids containing	one atom of H	are called	Monobasic.
"	"	two atoms	"	Dibasic.
"	"	three atoms	"	Tribasic.

Def. of Base.—A base is a compound, usually an oxide or hydrate, containing a metal (or group of elements) capable of replacing the H of an acid. Bases are generally metallic oxides.

Def. of an Alkali.—An alkali is a base of a specially active character, soluble in water, to which it imparts a soapy taste and touch. Alkalies restore the blue colour to reddened litmus.

Def. of Hydrates.—Hydrates are mostly compounds of metallic oxides with water.

Def. of a Salt.—A salt is the product of the action of an acid on a base.

MODES OF CHEMICAL ACTION—

I. Direct union.
II. Chemical displacement.
III. Mutual exchange.
IV. Re-arrangement of particles.
V. Direct decomposition.

COMPOSITION OF THE ATMOSPHERE—

(*a*)	Oxygen	=	20·61.
	Nitrogen	=	77·95.
	Carbonic dioxide	=	·04.
	Aqueous vapour	=	1·4.
	Nitric Acid	=	Traces.
	Ammonia	=	Traces.
	Carburetted Hydrogen	=	Traces.
In towns and manufacturing districts.	Sulphuretted Hydrogen	=	Traces.
	Sulphur dioxide	=	Traces.

(*b*) The average composition of the atmosphere when freed from CO_2 and Aqueous vapour is—

Nitrogen,	79·19	by volume.
Oxygen,	20·81	by volume.
Nitrogen,	76·99	by weight.
Oxygen,	23·01	by weight.

NOTES.—(*a*) In Chemical calculations the Metric System is used.

The Greek prefixes deca, hecto, kilo represent 10, 100, and 1000 respectively.

The Latin deci, centi, milli represent a tenth, a hundredth, and a thousandth respectively.

(*b*) 1 metre = 39·37 inches.

(*c*) 1 litre = 61·027 cubic inches or 1·7607 pints.

A litre is the volume occupied by a kilogram of water at 4° C., and it is equal to a cubic decimetre.

∴ 1 gram = 1 cubic centimetre.

(*d*) 1 gram = 15·4323 grains.

(*e*) 1 cubic foot of water at 4° C. weighs 1000 ozs.

(*f*) 1 litre of H at 0° C. and 760 mm. pressure = crith = ·0896 gram.

(*g*) Prof. Williamson's standard—

11·2 litres of H = 1 gram.
" " O = 16 grams.
&c. &c. &c.

SECTION VI.

HEAT AND LIGHT.

A. Heat—

I. Theories as to its Nature—

(*a*) The Emission or Material Theory supposes—

1. Heat consists of an imponderable substance surrounding the molecules of bodies.
2. These heat atmospheres are self-repellant, and therefore heat acts in opposition to the force of cohesion.

(*b*) The Dynamical Theory is the one universally held, and supposes—

1. Heat to be caused by the rapid vibratory motion of its particles.
2. The hottest bodies are those in which these vibrations have the greatest velocity and amplitude.
3. The molecules of warm bodies are capable of communicating a vibratory motion to the imponderable elastic ether (which is assumed to pervade all matter and all space), and thus neighbouring bodies become heated.

II. Expansion of Solids, Liquids, and Gases—

Coefficient of Expansion.—(*a*) The Coefficient of Expansion is that fraction of a body's length which it expands on being heated 1° C.

The coefficient of cubical expansion is approximately three times the linear expansion.

Boiling Point of Liquid.—(*b*) The boiling point of a liquid is that point of temperature at which the tension of its vapour equals the pressure it supports.

The boiling point is lowered 1° C. for every 1060 feet of elevation.

Maximum Density of Water.—(*c*) Water is at its maximum density at 4° C.

Gay Lussac's Laws—

(*d*) (1) All gases have the same coefficient of expansion as air.

(2) This coefficient is the same whatever be the pressure supported by the gas. (This coefficient $= \frac{11}{3000}$ or $\frac{1}{273}$).

III. Thermometry—

Temperature—

(*a*) The temperature of a body is the greater or less extent to which it tends to impart sensible heat to other bodies.

Thermometers—

(*b*) (1) To convert Fahrenheit degrees to Centigrade $(F. - 32)\ \frac{5}{9} = C.$

(2) To convert Centigrade degrees to Fahrenheit $(\frac{9}{5}\ C. + 32) = F.$

(3) To convert Réaumur degrees to Fahrenheit $(\frac{9}{4}\ R. + 32) = F.$

(4) To convert Fahrenheit degrees to Réaumur $(F. - 32)\ \frac{4}{9} = R.$

IV. Calorimetry and Specific Heat—

Thermal Unit.—(*a*) The thermal unit is the quantity of heat required to raise 1 lb. of water 1° C. at the standard temperature.

Specific Heat.—(*b*) The Specific Heat of a body is the relation between the quantity of heat required to raise the body and that required to raise an equal weight of water through 1° C.

V. Solidification and Liquefaction—

Laws of Solidification—

(*a*) 1. Every body under the same pressure solidifies at a fixed temperature, which is the same as that of fusion.

2. From the commencement to the end of solidification the temperature of a liquid remains the same.

Laws of Liquefaction or Fusion—

(*b*) 1. Every body under the same pressure begins to fuse at a fixed temperature.

2. From the commencement to the end of liquefaction the temperature of the substance remains the same.

VI. Vaporization, Condensation, and Ebullition—

(*a*) Vaporization is used to denote the change which takes place when a liquid passes into the gaseous state. It includes Evaporation and Ebullition.

(*b*) The condensation of vapours may be due to cooling, compression, or chemical affinity.

(*c*) *Laws of Ebullition*—

1. The temperature of Ebullition, or the boiling point, increases with the pressure.

2. All liquids begin to boil at a temperature which for each liquid is constant under a constant pressure.
3. As soon as ebullition begins, the temperature of the liquid remains stationary.

(*d*) *Laws of Evaporation*—

1. Evaporation takes place more rapidly the greater the surface exposed.
2. It increases with the increase of temperature.
3. It decreases as the air becomes more and more saturated with the same vapour.

VII. Latent Heat—

Latent Heat is the quantity of heat which disappears, and is not shown on the thermometer when the molecular constitution of a body is being changed.

(*a*) Latent Heat of Fusion of Water is 80 thermal units.
(*b*) " " Evaporation " 536 " "

VIII. Conduction and Convection—

(*a*) Heat is transmitted by Conduction when each atom takes up the motion of its neighbour and sends it on to others.

(*b*) Heat is transmitted by Convection when it is propagated in a liquid or gas by the motion of its heated particles.

B. Light—

Theories—

I. Emission Theory—supported by Newton—

(*a*) Light consists of an imponderable substance, consisting of corpuscles of matter.

(*b*) These corpuscles are emitted from luminous bodies with enormous velocity, and by their impact on the retina of the eye produce the sensation of vision.

II. THE UNDULATORY THEORY—now generally accepted—

(*a*) There exists in space an exceedingly rarefied but very elastic substance called 'ether,' which also surrounds the molecules of matter.

(*b*) The particles of luminous bodies are in a state of extremely rapid vibration.

(*c*) These vibrations are generated in the ether as undulations, and proceed with great velocity in concentric spheres.

(*d*) By the impact of these waves upon the retina, the sensation of vision is caused.

Velocity of Light—

Rœmer's	method	gave	192,000	mls. per	second.
Bradley's	"	"	190,860	"	"
Foucault's	"	"	185,157	"	"
Fizeau-Cornu's	"	"	186,616	"	"

Intensity of Light—Laws—

1. The intensity of illumination is inversely as the square of its distance.

2. The intensity of illumination which is received obliquely is proportional to the cosine of the angle which the luminous rays make with the normal to the illuminated surface.

Photometers.—A Photometer is an apparatus for measuring the relative intensities of light. The principal are Rumford's, Bunsen's, and Wheatstone's.

Reflection at plane or spherical surfaces—

(A) Laws of the Reflection of Light—

1. The angle of reflection equals the angle of incidence.
2. The incident and the reflected rays are both in the same plane, and this is perpendicular to the reflecting surface.

(B) Relative velocity of mirror and image—

1. If a mirror be moved parallel to itself, either from or towards an object, the image moves twice as fast as the mirror.
2. If a mirror be made to rotate, the angle through which the image moves is twice the angle through which the mirror moves.

Real and Virtual Images.—Real images are those formed by the reflected rays themselves. Virtual images are those formed by the prolongation of the reflected rays.

Refraction—Laws of—

1. The sine of the angle of incidence bears to the sine of the angle of refraction a constant ratio for the same two media.

2. The incident and refracted rays are in the same plane, and that plane is perpendicular to the common surface of the two media.

N.B.—Refraction is always accompanied by Reflection—the higher the refractive power the greater the amount of Reflection.

The critical angle of Refraction for water and air is $48\frac{1}{2}°$.

Formula for Spherical mirrors—

Let f = focal distance; p = distance of object from mirror; and p' = distance of image from mirror,

$$\text{then } \frac{1}{p} + \frac{1}{p'} = \frac{1}{f}.$$

Magnitude of Images in Mirrors—

Length of image: length of object :: distance of image from centre: distance of object from centre.

Lenses.—Lenses are transparent media, which, from the curvature of their surfaces, have the property of causing the luminous rays which traverse them either to converge or diverge.

Decomposition of White Light by a Prism.—In the Solar Spectrum there are seven principal colours :—Violet, indigo, blue, green, yellow, orange, and red (v. i. b. g. y. o. r.). The violet is the most, and the red the least refrangible.

These colours can be recombined to form white light by—

(*a*) Taking another prism of the same refracting angle as the dispersing one and placing near the other in an inverted position.

(*b*) Allowing the decomposed beams to fall upon a concave mirror.

(*c*) Using Newton's disc.

SECTION VII.

MAGNETISM AND ELECTRICITY.

A. Magnetism—

I. Laws of Magnetic Force—

1. Like magnetic poles repel one another; unlike poles attract.

2. The force exerted between two magnetic poles is proportional to the product of their strengths, and is inversely proportional to the square of the distance between them.

II. Differences between Magnets and Magnetic Substances—

1. Magnets attract only at their poles; they possess opposite properties, and also 'magnetic equators.'

2. Magnetic substances are those which attract either pole of the magnet; they have no fixed 'poles' and no 'magnetic equators,' such as iron, steel, nickel, cobalt, and in a much inferior degree chromium and manganese.

III. Diamagnetic bodies—

The following are repelled from the poles of a magnet, and are known as diamagnetic bodies:—Bismuth, phosphorus, antimony, and copper.

IV. Def. of Poles—

Opposite properties in opposite directions so exactly equal as to be capable of accurately neutralising each other.

V. Methods of making Magnets—

1. Single touch.
2. Divided touch.
3. Double touch.

VI. Coercive Force or Retentivity

Is the force by which a magnetic substance resists the decomposition and the recomposition of the magnetic fluids.

VII. Magnetic Force may be measured in three ways—

1. Balance it against the torsion of an elastic thread.

2. By observing the time of swing of magnetic needle, oscillating under its influence.

3. Observe deflection produced in needle, which is already attracted in different direction by a force of known intensity.

VIII. The earth a Magnet—

North Magnetic Pole 70° 5′ N. Latitude, and 96° 46′ W. Longitude.

South Magnetic Pole has never been reached, but there appear to be two south polar regions.

IX. Declination—

The angle between the geographical meridian and the magnetic meridian is called the Declination of that place.

In London now the angle of declination is about 17° 40′ West of true N.

X. Inclination or Dip—

This is the angle which the magnetic needle makes with the horizon.

In the north hemisphere the north pole dips; in the south the south pole dips. The inclination at London is about 67° 25′.

XI. Three things must be known to specify the Magnetism of any place—

1. The Declination.
2. The Inclination.
3. The Intensity of Magnetic Force.

XII. Agonic lines are lines of no variation of Declination —where the Magnetic and Geographical Meridians coincide.

XIII. Earth's Magnetic Equator, or the Aclinic line, is the line round the earth upon which the dipping needle remains in a horizontal position.

XIV. Isogonic lines are lines of equal declination.

XV. Isoclinic lines are lines of equal dip.

XVI. Paramagnetic substances are those which are attracted by powerful electro-magnets.

B. Electricity.

I. Frictional :—

Law I. Like electricities repel, unlike attract.

Theories of Electricity :—

A. Symmer's—Two fluid theory supposes—

1. There are two imponderable electric fluids of opposite kinds.

2. They neutralise each other when they combine.
3. They exist combined in equal quantities in all bodies until the condition is disturbed by friction.

B. Franklin's Theory supposes—

1. One fluid only.
2. When bodies are not neutral, they are charged with a positive quantity (+), or a negative quantity (-) of the same fluid.

C. Molecular Theory. — Faraday conceives electrical induction to depend on a physical action between the contiguous molecules, which takes place at a distance by operating through the intervening particles of non-conducting matter. He also supposes that in this medium successions of layers become alternately, positively and negatively electrified. This condition is called 'Dielectric Polarisation.'

Coulomb's Laws—

1. The repulsions and attractions between two electrified bodies are in the inverse ratio of the squares of their distances.
2. Distance being the same, the attractive or repulsive force is directly as the product of the charge.

Electrical Induction is the action of an electrified body exerted at a distance upon the electricity of another body.

Inductive Capacity.—The power of a body to allow the inductive influence of an electrified body to act across it is called its Inductive Capacity.

The Capacity of a Condenser depends upon—

1. The size and form of the metal plates or coatings.
2. The thinness of the stratum of insulator between them.
3. The inductive capacity of insulator.

B. **Electricity**—

II. Current or Dynamical :—

(*a*) *Definition*—

1. The strength of a current is the quantity of electricity which flows past any point of the circuit in one second.

2. Electromotive-Force (E.M.F.) is that which moves or tends to move electricity from one place to another.

(*b*) *Volta's Laws*—

I. The difference of potential between any two metals is equal to the sum of the differences of potential between the intervening metals in the contact series.

II. The total electromotive-force of a series of cells, the zincs and coppers of which are all arranged in one order, will be equal to the electromotive-force of one cell multiplied by the number of cells.

(*c*) *Laws of Chemical Action in the Cell*—

I. The amount of chemical action in the cell is proportional to the quantity of electricity that passes through it—that is, it is proportional to the strength of the current.

II. The amount of chemical action (in a battery consisting of cells joined in a series) is equal in each cell.

Joule's Law.

(*d*) *Heating Effects of Current*—

The number of units of heat developed in a conductor is proportional

1. To its resistance.
2. To the square of the strength of the current.
3. To the time that the current lasts.

(*e*) *Laws of Electrolysis*—

1. Electrolysis cannot take place unless the electrolyte is a conductor.

2. The energy of the electrolytic action of the current is the same in all its parts.

3. The same electric current decomposes chemically equivalent quantities of all the bodies which it traverses.

4. The quantity of a body decomposed in a given time is proportional to the strength of the current.

(*f*) *Magnetic Effects of Currents—Ampère's Law—*

To keep movements of a magnet acted on by a current in memory—Suppose a man swimming in the wire with the current, and that he turns so as to face the needle, then the N-seeking pole of the needle will be deflected towards the *Left*-hand.

(*g*) *Ohin's Law—*

The strength of the current varies directly as the electromotive-force, and inversely as the resistance of the circuit.

This is expressed by formula

1. $$C = \frac{E}{R} \qquad (1)$$

where C = current, E = electromotive-force, R = resistance.

2. The resistance of a conductor depends on three elements—its conductivity, section, and length.

$$R = \frac{l}{cs}$$

Where l = length, c = conductivity, and s = section of conductor, so formula (1) now becomes

$$C = \frac{\frac{E}{e}}{cs} = C = \frac{csE}{e}$$

3. There are two resistances, that between the two plates immersed in liquid and that offered by the conductor which connects the places outside the liquid. Calling the former R and the latter r, the formula becomes

$$C = \frac{E}{R + r}$$

4. Formula for any number (n) of similar cells joined together where the external resistance is very small.

$$C = \frac{nE}{nR} = \frac{E}{R}$$

5. Formula, when external resistance is great, as in the production of electric light, becomes

$$C = \frac{nE}{nR + r}$$

if r is very great as compared with nR, the latter may be neglected and formula becomes

$$C = \frac{nE}{r}$$

Laws of Electro-magnets—

1. The strength of an electro-magnet is proportional to the strength of the magnetising current.

2. The strength of an electro-magnet is proportional to the number of turns of wire in the coils.

3. The strength of an electro-magnet is independent of the thickness and material of the conducting wire.

4. The strength of an electro-magnet is independent of the diameter of the coils.

5. A current of electricity requires time to magnetise an iron core to the full extent of its power.

Laws of Magneto-electric Induction—

1. A decrease in the number of lines-of-force which pass through a circuit produces a current round the circuit in the positive direction (*i.e.*, produces a direct current), while an increase in the number of lines-of-force which pass through the circuit produces a current in the negative direction round the circuit.

2. The total induced electro-motive force acting round a closed circuit is equal to the rate of decrease in the number of lines-of-force which pass through the circuit.

Lenz's Law.—In all cases of electro-magnetic induction the induced currents have such a direction that their reaction tends to stop the motion which produces them.

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